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METHOD OF TESTING PANEL TYPE AIR FILTERS FOR AIR-CONDITIONING AND VENTILATION PURPOSES

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Indian Standard

METHOD OF TESTING PANEL TYPE AIR FILTERS FOR AIR-CONDITIONING AND VENTILATION PURPOSES

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 27 February 1975, after the draft finalized by the Refrigeration and Air-Conditioning Sectional Committee had been approved by the Mechanical Engineering Division Council.

0.2 This standard relates exclusively to the methods of testing panel type air filters for air-conditioning and general ventilation purposes and does not cover the performance requirements. It is primarily intended for bench testing of air filters used for air-conditioning and general ventilation purposes with penetration not less than 0·01 percent. The following two tests are included:

a) Determination of methylene blue penetration, and

b) Determination of dust holding capacity and gravimetric retention efficiency.

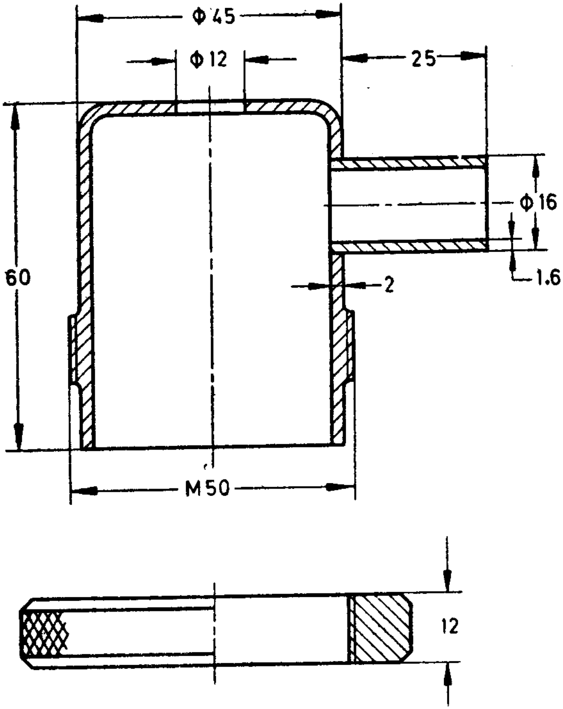
SECTION 1 DETERMINATION OF METHYLENE BLUE PENETRATION

1.1 Scope — This section deals with the determination of methylene blue penetration employing staining effect as the criterion.

1.2 Methylene Blue Penetration Test — A methylene blue cloud shall be generated continuously by the evaporation of a mist formed by atomizing a solution of the dye. The staining power of the cloud before and after passage through the filter shall be determined by a suitable optical densitometer measuring optical density of samples taken on filter paper. From these measurements the penetration of the filter shall be calculated.

1.3 Apparatus for Production of Test Cloud

1.3.1 *Atomizer* — The various components of the atomizer shall be as shown in Fig. 1 to 3 and shall be assembled in the manner indicated in Fig. 4. To provide the necessary quantity of test cloud in a reasonable time, a number of atomizers may be used in parallel.



All dimensions in millimetres.

FIG. 1 ATOMIZER HEAD AND NUT

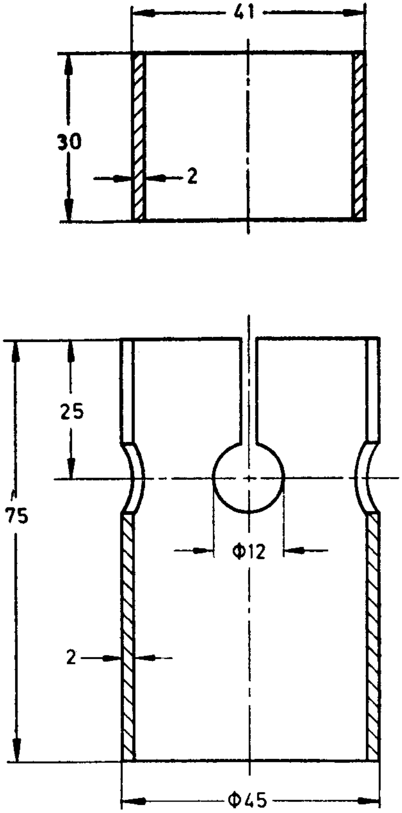


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FIG. 2 SLEEVES

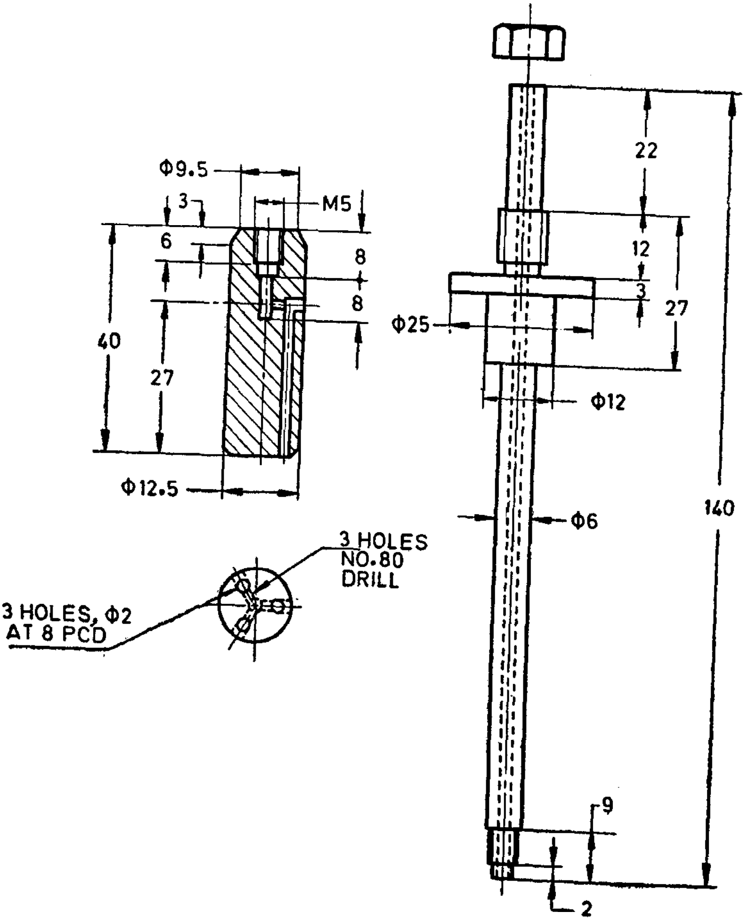

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FIG. 3 NOZZLE AND SPINDLE

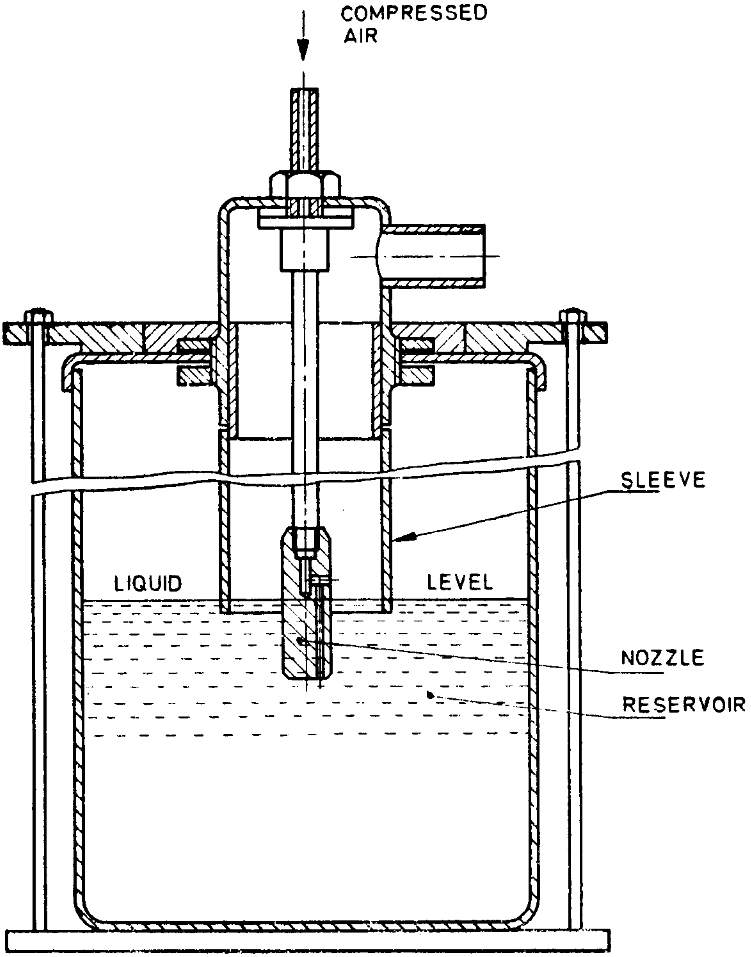

Fig. 4 Atomizer Assembly

1.3.2 *Compressed Air Flowmeter* — A compressed air flowmeter to measure a flow of 8 to 9 litres per minute of free air at a pressure of 200 kPa shall be provided. A suitable design of the ball and curved tube type is shown in Fig. 5 and 6.

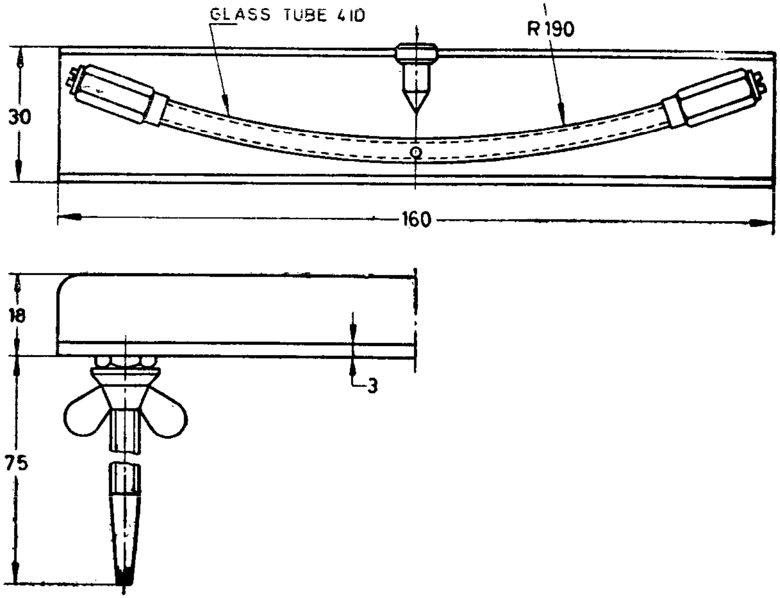

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FIG. 5 COMPRESSED AIR FLOWMETER

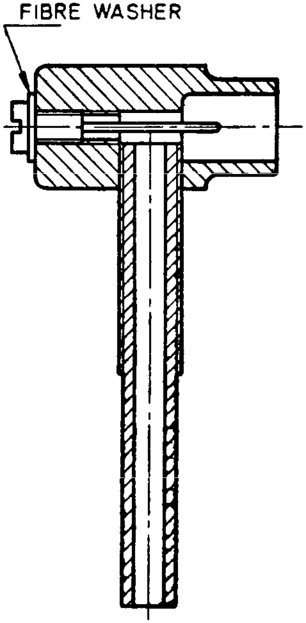


FIG. 6 END CONNECTOR

1.3.3 *Pressure Gauge* — A pressure gauge of the bourdon type reading up to 300 kPa with a dial of not less than 100 mm shall be provided.

1.3.4 *Regulator Valve* — A valve suitable for controlling air flow of 8 to 9 litres per minute at a pressure of 200 kPa shall be provided.

1.3.5 *Compressed Air Supply* — A source of compressed air capable of delivering 10 litres per minute of free air per atomizer at a constant pressure of 250 kPa shall be provided. Oil and water free clean air shall be fed to the atomizers. The supply pressure shall remain constant within 5 to 10 kPa.

1.3.6 *Connections* — The system for generating the test cloud shall be connected as shown in Fig. 7.

1.3.7 *Calibration of System* — The atomizer connected as in Fig. 7 shall be assembled without any liquid in the reservoir and the outlet tube connected to a free air flowmeter. The compressed air shall be turned on and regulated until a steady pressure of 200 kPa is reached. If the atomizer jets are in order, the flow recorded on the free air flowmeter should be between 8 and 9 litres per minute. Set the marker of the compressed air flowmeter to the indicated position. If the free air flowmeter does not register a flow of 8 to 9 litres per minute, the atomizer shall be examined and corrected for defects in the jets, leaking connections and other faults. During operation of the atomizer the flow of compressed air shall be within ±1 litre per minute of the value set.

1.3.8 *Filling of Atomizer* — Prior to use, the atomizer shall be charged with one percent solution of methylene blue to a level of 5 mm below that of spray jets.

1.4 Test Rig — The test rig which shall be set-up in a reasonably dust free atmosphere shall consist of the following sections:

a) An inlet section of such diameter (D) that the linear velocity of air through the section does not exceed 9 m/s. The inlet section shall be 15 D in length and a circular baffle of diameter $D/\sqrt{2}$ shall be fixed centrally at a distance of 10 D from the inlet end by means of sharp strips.

b) An expanding section followed by a parallel section as shown in Fig. 8.

c) A reducing section as shown in Fig. 8.

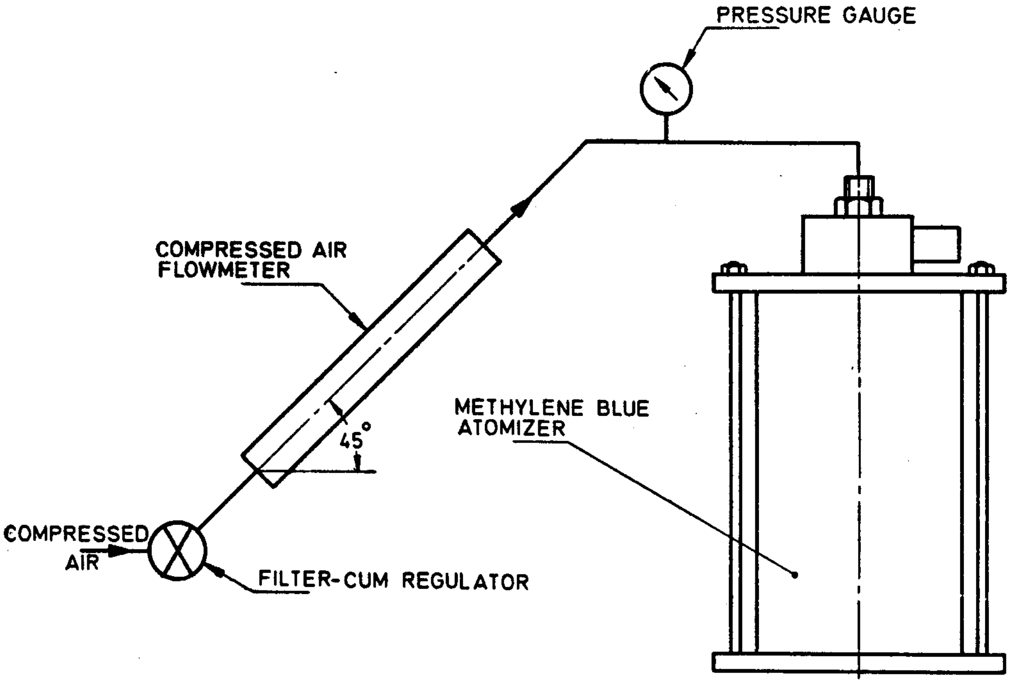


Fig. 7 Atomizer Air Supply Connections

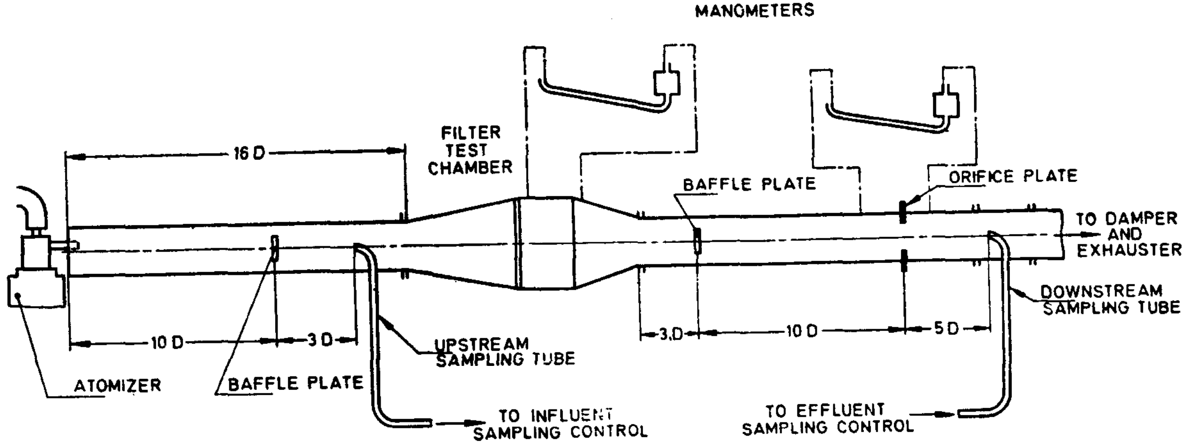


Fig. 8 Test Rig Layout

d) An outlet section of suitable length accommodating a mixing baffle and an orifice plate baffle at a distance of $3D$ downstream of the junction of the reducing section and outlet section.

e) An exhauster capable of setting up the greatest depression required to give the rated air flow through the test filter under all conditions, shall be connected to the end of the outlet section. Suitable damper shall be provided for adjustment of air flow rate.

1.5 Ancillary Equipment — The following shall be provided in the test rig:

a) An orifice plate with D and $D/2$ pressure taps constructed and installed in accordance with IS : 2952(Part II)* and a suitable differential manometer.

b) Static pressure taps at front and back faces of the test filter.

c) Thin walled sampling tubes as shown in Fig. 9 inserted axially in the duct in front of and behind the test filter. The sampling tube in front of the filter shall be inserted in the inlet section at a distance of $13D$ from the inlet end and that behind the filter shall be $5D$ downstream from the orifice plate (*see* Fig. 8). The sampling tubes incorporate filter paper holders as shown in Fig. 10. The sampling tubes shall be connected to the integrating dry gas meters of suitable types or alternatively connected to capillary type flowmeters in a constant flow sampling device as shown in Fig. 11.

d) A photometric densitometer for measuring optical density of the stains.

e) Sampling filter papers having the characteristics given in Appendix A.

1.6 Condition of Air — The air shall be maintained at a temperature of 30 to 45°C with relative humidity of 40 to 75 percent. The aspirated air shall be such that when 150 litres of air is drawn through the filter paper, there is no visible stain on the paper.

1.7 Test Procedure — The filter to be tested shall be set in place in the test rig and the exhauster started. Damper shall be set to allow the rated quantity of air to flow through the filter. The atomizer shall be mounted with the nozzle vertical and the outlet pipe pointing into the inlet section of the test rig just axially. Clean filter papers shall be inserted into the sample holders. The exhauster, atomizer and the suction pump shall be set in operation adjusting the sampling rates isokinetically. Both unfiltered and filtered air shall be sampled for suitable lengths of time such that the intensified stains from both the samples shall have approximately the same optical density.

---

*Recommendation for methods of measurement of fluid flow by means of orifice plate and nozzles: Part II Compressible fluids.

The resistance of the test filter is obtained by reading water manometer connected with static pressure taps at front and back faces of the filter.

The above test shall be repeated on the same filter using same conditions until the values of optical densities for the unfiltered and filtered air for any three tests agree with the average value within ±3 percent. If this agreement is not achieved after 5 tests, the reasons for the scatter shall be determined and rectified. If this agreement is not achieved after a further set of 5 tests, record shall be made while reporting the results and all the ten values of the methylene blue penetration shall be given.

1.8 Calculations

1.8.1 *Optical Density of Stain* — Let L_o be the reading of the densitometer on an evenly divided scale (zero = dark) for the clean filter paper. Let L be the corresponding reading for the stained paper. Optical density of the stain is, thus, log (L_o/L). Provided L, the optical density lies between 0·2 to 0·5, the relationship with the volume of the sample is given by:

$$L - L_o = C\,V$$

where

C = constant, and

V = volume of sample drawn.

1.8.2 *Determination of L_o* — It is necessary to determine L_o for each batch of filter paper experimentally, computing the results from the following formulae:

$$C = \frac{\Sigma\, L\cdot V - \Sigma\, L\, \Sigma\, V/n}{\Sigma\, V^2 - \Sigma\,(\,V\,)^2/n}$$

$$L_o = \frac{\Sigma\, L - C\, \Sigma\, V}{n}$$

where

C = constant depending upon cloud concentration and nature of filter paper,

V = volume of sample drawn, and

n = number of papers sampled.

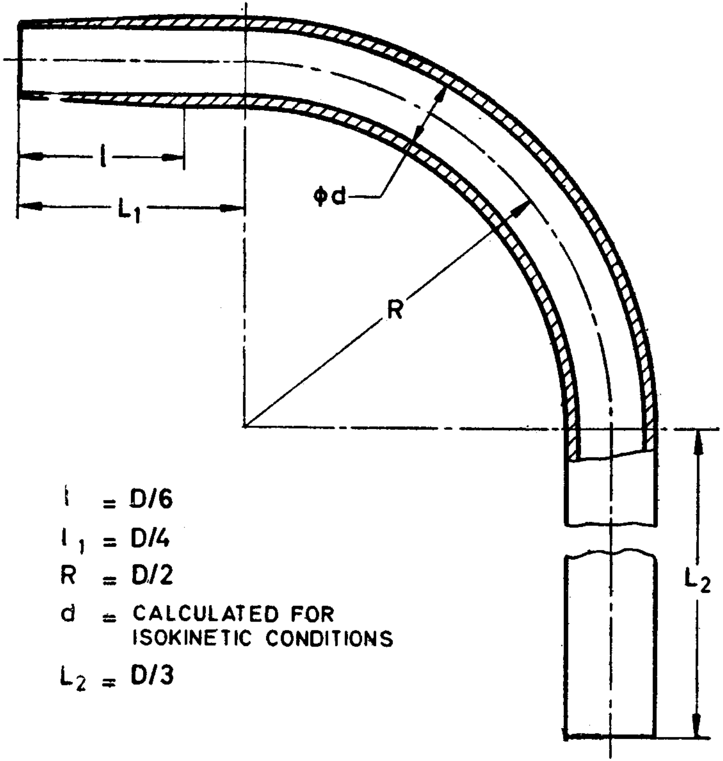


Fig. 9 Sampling Tube

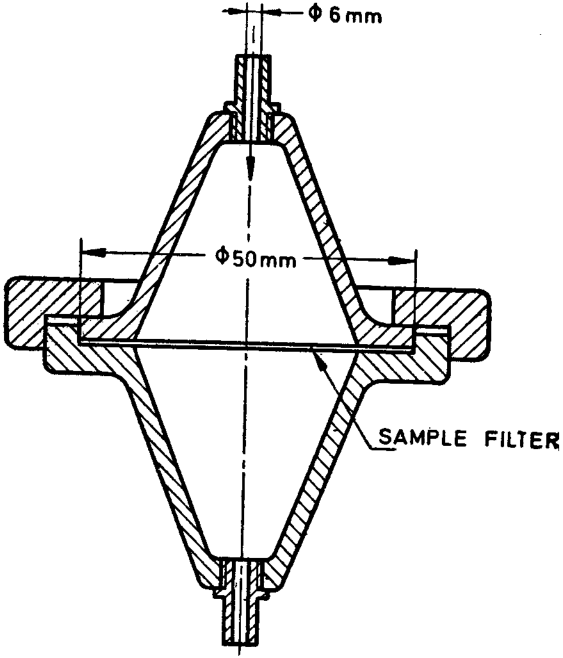


Fig. 10 Sample Filter Holder

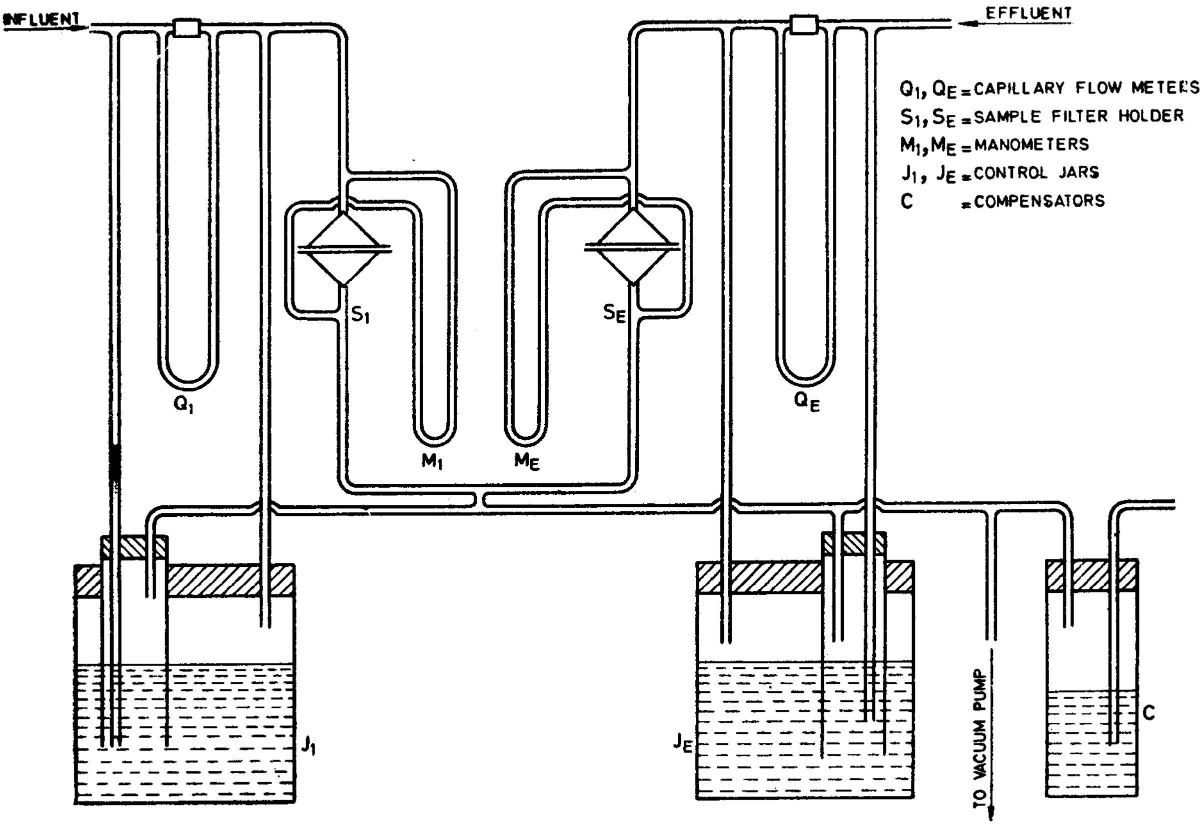


Fig. 11 Constant Flow Sampling Device

1.8.3 *Value of Methylene Blue Penetration*

$$\text{Methylene blue penetration (percent)} = \frac{V_1 (L_2 - L_o)}{V_2 (L_1 - L_o)} \times 100$$

where

V_1 = volume of unfiltered air,
V_2 = volume of filtered air,
L_2 = optical density of filtered air, and
L_1 = optical density of unfiltered air.

SECTION 2 DUST HOLDING CAPACITY GRAVIMETRIC RETENTION EFFICIENCY TEST

2.1 Scope — This section deals with the determination of dust holding capacity and gravimetric retention efficiency test.

2.2 Grades of Test Dust — For the purpose of identification the grades of test dust shall be classified as under:

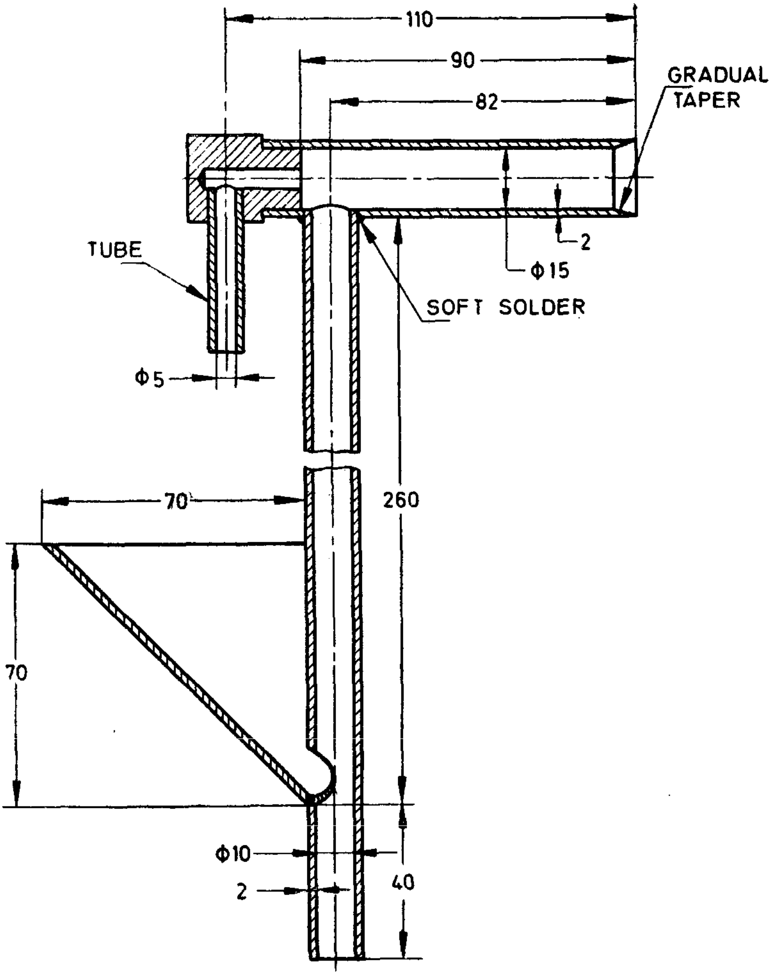
a) Test Dust G1: Methylene blue cloud (*See* Appendix B)
b) Test Dust G2: Fused aluminium oxide (*See* Appendix B)
c) Test Dust G3: Fused aluminium oxide (*See* Appendix B)

2.3 Gravimetric Retention Efficiency — Gravimetric retention efficiency of the filter when tested with test dust G2 or G3 is defined as:

$$\frac{\text{Weight of dust retained on filter}}{\text{Weight of total amount of dust fed}} \times 100 \text{ (percent)}$$

2.4 Dust Holding Capacity — Dust holding capacity of a filter is the weight of dust retained by the filter during the test period in which its resistance rises from the initial value (when clean) to 0·12 kPa (approximate 12 mm H_2O) above the initial resistance or to twice the initial resistance whichever is greater. The filter shall be tested with one or more of the test dusts as required to determine the dust holding capacity and gravimetric efficiency. Each test shall be divided into three cycles, arranged to cover approximately equal increments of resistance until the final resistance specified is reached. The test dust shall be inducted at the mouth of the inlet pipe at a steady rate by the feeding mechanism (dust feeding injector) shown in Fig. 12.

2.5 Apparatus for Dispersal of Test Dusts G2 and G3 — The dust shall be free flowing and dry contributing in maintaining a constant and controlled feed rate. The feeding mechanism is shown in Fig. 12. The feed rate may be controlled by varying the amplitude or frequency of vibrations.



All dimensions in millimetres.

Fig. 12 Dust Feeding Injector

2.6 Test Rig — The test rig shall consist of various sections given in Section 1. It shall be set up in a reasonably dust free atmosphere.

2.7 Ancillary Equipment — The ancillary equipment and test procedure shall be classified into two groups as follows, depending upon the technique adopted:

a) Employing weighing of filter before and after test, and
b) Employing air stream sampling technique.

2.7.1 *Balance for Weighing the Filter and Test Dust* — The balances and weights shall meet the following requirements for accuracy:

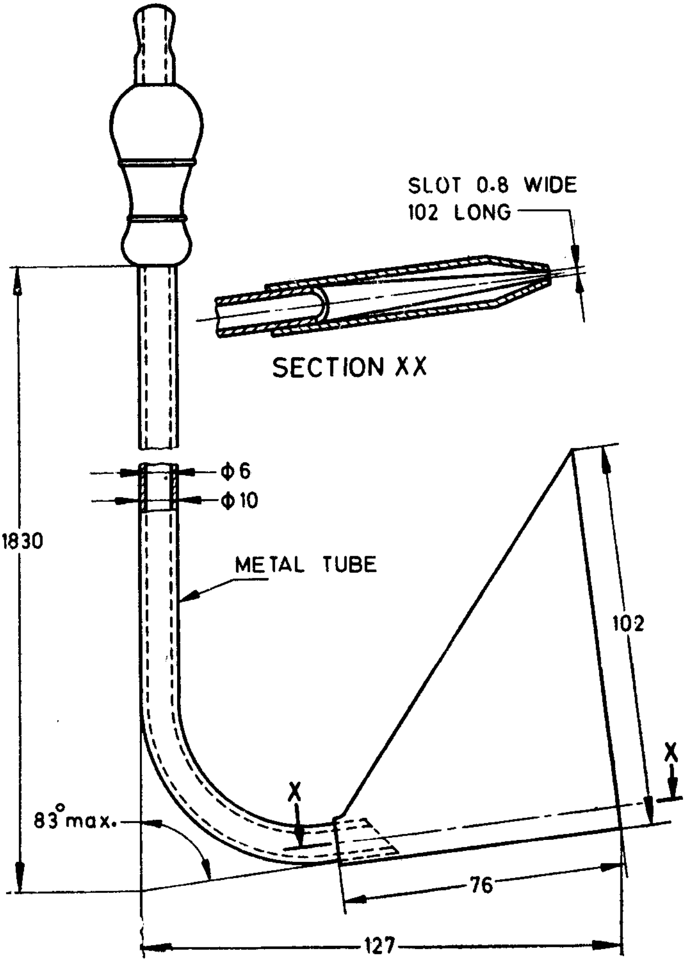
Capacity g	*Sensitivity* g
500	0·05
2 000	0·1
10 000	0·5
Over 10 000	2

2.7.2 *Wander Lead* — A compressed air wander lead to redisperse dust collected on the floor of the test duct shall be provided in such a manner that a direct jet of compressed air cannot impinge upon the filter face. A suitable design is shown in Fig. 13. Air pressure of 100 to 150 kPa at the entry to the wander lead is satisfactory.

2.8 Condition of Air — The aspirated air shall be clean and free from fumes and shall be maintained at a temperature of 30 to 45°C with relative humidity of 40 to 75 percent. This should remain steady while testing dry fabric type of filter panels.

2.9 Procedure — The filter to be tested shall be in a clean condition and viscous impingement type of filters shall be serviced and charged with oil in accordance with the manufacturers' recommendations. They shall be allowed to drain at the ambient temperature for a period of 24 hours before subjecting to test. After weighing, the filter shall be set in place in the test rig ensuring perfect sealing.

2.10 Determination of Initial Resistance Characteristic — Test shall be carried without dust being fed to the filter. The volume of air passing through the filter shall be found from the readings of orifice plate flowmeter and resistance shall be recorded after it has remained constant for 5 minutes, using rates of flow approximating to 40, 60, 80, 100 and 120 percent of the filter rated capacity.



All dimensions in millimetres.

Fig. 13 Wander Lead

2.11 Determination of Oil Carry Over Characteristic — This applies to viscous impingement type of air filters. The test shall be in continuation of initial resistance test. The flow-rate shall be set at its rated capacity and shall be maintained for a period of one hour. The air temperature, relative humidity and change in resistance shall be recorded throughout the test. At the end of this period the filter shall be re-weighed and the loss of oil, if any, shall be ascertained. If the loss in weight has occurred, the test shall continue for half-hour periods until a constant filter weight is achieved. The total loss in weight shall be recorded as oil loss.

2.12 Determination of Retention Efficiency — Prior to testing a dry type filter, clean air at rated capacity shall be passed through the filter for 30 minutes to allow it to become normalized.

2.12.1 Using some prior knowledge of the dust holding capacity of the filter, the total load which the filter shall carry for the final resistance shall be assessed. Where practicable, this quantity of dust should be fed during a period of 4 to 5 hours to realize the approximate dust concentration in mg/m^3.

2.12.2 Adjust the feed rate of the dust feeding device to obtain the required dust concentration.

2.12.3 Introduce a weighed quantity of test dust into the feed hopper. Switch on the exhauster and adjust air flow to the rated flow capacity. Record resistance, air temperature and relative humidity.

2.12.4 Set the feeder in operation. Note the filter resistance at regular intervals. Carry the test till the specified resistance is reached. Record final resistance, air temperature and relative humidity. Switch off the exhauster, weigh dust remaining in the dust feed hopper and ascertain the dust fed to the filter. Any dust remaining in the approach section of the test duct shall be recovered and the weight added to that of the dust remaining in the hopper.

2.12.5 Remove test filter from the housing and weigh to ascertain the weight of dust retained. Compute the retention efficiency of the filter by the formula given in **2.3**.

2.13 Method of Determining Retention Efficiency of the Filter by Sampling Technique — This method comprises of ascertaining the dust concentration in air stream before and after the filter. The same sampling tubes and sampling filter holders as those required for determining methylene blue penetration are utilized for the purpose and care is taken that precise isokinetic conditions prevail while sampling the air streams.

The filter paper before being placed in the sampling holder is dried in an oven at 110°C for 20 minutes, cooled in desiccator for 20 minutes and weighed in an analytical balance sensitive to 0·1 mg:

If

D = ducting diameter,
Q = rated flow capacity,
d = sampling tube diameter,
t = duration of sampling, both for influent and effluent streams,
w_1 = increase in weight of filter paper on the influent side,
w_2 = increase in weight of filter paper on the effluent side, and
T = test duration.

Then, amount of dust fed, $W_1 = (w_1 D^2 T/d^2 t)$,

amount of dust let off by test filter, $W_2 = (w_2 D^2 T/d^2 t)$, and

$$\text{retention efficiency} = \frac{(W_1 - W_2)}{W_1} \times 100 \text{ percent.}$$

NOTE — Proper relationships shall be used if the diameters of sampling tubes or durations of sampling are unequal.

2.14 Reporting — Test results shall be reported along with the following graphs:

a) The initial resistance plotted against air flowrate.
b) The resistance at the end of each cycle plotted against the total quantity of dust retained on the filter at that time.
c) The gravimetric retention efficiency during each cycle plotted against the average quantity of dust on the filter during that cycle.

APPENDIX A

[*Clause* 1.5 (e)]

SAMPLING FILTER PAPER

A-1. Sampling filter paper for methylene blue penetration test shall be made from pure bleached esparto fibres having the following characteristics:

Basic weight	85 ± 5 g/m^2
Thickness	$0·2 \pm 0·02$ mm
Air resistance	$0·5 \pm 0·1$ kPa ($\approx 50 \pm 5$ mmH$_2$O)

A-2. For dust holding capacity and retention efficiency tests standard fibre glass or Whatman No. 50 filter paper discs are satisfactory.

APPENDIX B

(*Clause* 2.2)

GRADES OF TEST DUST

B-1. Test Dust G1 — Cloud generated by atomizing one percent solution of methylene blue dye with the help of atomizer shown in Fig. 1 to 4. Fully dispersed cloud varies in size from 0·01 µm to approximately 1·5 µm with a mean particle size of 0·5 to 0·6 µm.

B-2. Test Dust G2 — Fused aluminium oxide dust with the following particle size distribution by weight:

Less than 2·5 µm	2 percent
3·5 to 7 µm	60 to 80 percent
Less than 13 µm	99·5 percent

B-3. Test Dust G3 — Fused aluminium oxide dust with the following particle size distribution by weight:

Less than 10 µm	2 percent
15 to 25 µm	60 to 80 percent
Less than 35 µm	99·5 percent

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Plot No. 62-63, Unit VI, Ganga Nagar, BHUBANESHWAR 751001	40 36 27
Kalaikathir Buildings, 670 Avinashi Road, COIMBATORE 641037	21 01 41
Plot No. 43, Sector 16 A, Mathura Road, FARIDABAD 121001	8-28 88 01
Savitri Complex, 116 G.T. Road, GHAZIABAD 201001	8-71 19 96
53/5 Ward No. 29, R.G. Barua Road, 5th By-lane, GUWAHATI 781003	54 11 37
5-8-56C, L.N. Gupta Marg, Nampally Station Road, HYDERABAD 500001	20 10 83
E-52, Chitaranjan Marg, C-Scheme, JAIPUR 302001	37 29 25
117/418 B, Sarvodaya Nagar, KANPUR 208005	21 68 76
Seth Bhawan, 2nd Floor, Behind Leela Cinema, Naval Kishore Road, LUCKNOW 226001	23 89 23
NIT Building, Second Floor, Gokulpat Market, NAGPUR 440010	52 51 71
Patliputra Industrial Estate, PATNA 800013	26 23 05
Institution of Engineers (India) Building 1332 Shivaji Nagar, PUNE 411005	32 36 35
T.C. No. 14/1421, University P.O. Palayam, THIRUVANANTHAPURAM 695034	6 21 17

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